Biological Evaluation of the

Hemlock Stand at the Bird Run Campground of the

Monongahela National Forest, West Virginia

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ABSTRACT

In the fall of 2003, personnel from the USDA Forest Service, Monongahela National Forest (MNF) and the Northeastern Area, Forest Health Protection, Morgantown Field Office, conducted a hemlock woolly adelgid survey of the Bird Run Campground located along state route 84 in Pocahontas County. The purpose of this survey was to estimate hemlock woolly adelgid population densities through visual stand and tree inspections and to assess the need for treatment. Current populations are high enough to cause reduced growth and future mortality of infested trees. It is recommended that the MNF consider trunk injection treatment of 27[1] heavily to moderately infested hemlock trees and the release of 5,000 predatory beetle (*Pseudoscymnus tsugae)* to counter the exotic hemlock woolly adelgid (HWA), *Adelges tsugae*.

INTRODUCTION

Adelgids are small, soft-bodied insects that feed on plant sap. The family is divided into two genera: *Adelges* and *Pineus*. The members of this family feed exclusively on conifers. There are six species of *Adelges* that occur in North America, of which only one is native (Montgomery 1999)—the Cooley spruce gall adelgid (*Adelges cooleyi*). This adelgid occurs coast to coast in northern North America. Its primary hosts are recorded as white (*Picea glauca*), blue (*Picea pungens*), Sitka (*Picea sitchensis*), and Engelmann (*Picea engelmannii*) spruce (Baker 1972). It has an alternate host, Douglas fir (*Pseudotsuga menziesii*). There are 10 species of *Pineus* that occur in North America, of which seven are native. Four of these (the pine bark adelgid (*Pineus strobi*), the pine leaf adelgid (*P. pinifoliae*), the red spruce adelgid (*P. floccus*), and the spruce gall adelgid (*P. similes*)) seem to be indigenous to eastern North America (Drooz 1989, Montgomery 1999). These species attack eastern white pine (*Pinus strobus*), red spruce (*Picea rubens*), and black spruce (*Picea mariana*) but seldom cause extensive damage (Drooz 1989, Montgomery 1999). Little is known about the population dynamics, ecological role, or the predator and parasite complex associated with these native adelgids.

Native to Japan, the hemlock woolly adelgid (*Adelges tsugae*) (HWA) is a pest of eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*T. caroliana*) (Onken et al. 1999), both of which are considered highly susceptible to the adelgid, with no documented resistance (Bentz et al. 2002). The latter tree species is found only in the southern region of the Appalachian Mountains (Onken et al. 1999). The HWA is currently established in 15 Eastern States from Georgia to Maine, and tree decline and mortality have increased at an accelerated rate since the late 1980s. For example, in the Shenandoah National Park, hemlock crown health has declined since the early 1990s. In 1990, greater than 77 percent of the hemlocks sampled were in a "healthy" condition; by 1999, less than 10 percent were in a "healthy" condition (Akerson and Hunt 1998). New Jersey has estimated a loss of 9 percent of its hemlock resource and 44 percent remains moderately to severely impacted by HWA (Onken et al. 1999). Similar adelgid-caused impacts are also affecting most districts of the Monongahela National Forest.

[1] On-going surveys and proposed branch clipping will likely increase this number.

The hemlock woolly adelgid is parthenogenetic (an all-female population with asexual reproduction) and has six stages of development (the egg, four nymphal instars, and the adult) and two generations a year on hemlock[2]. Each adult adelgid can produce between 50 to 300 eggs in its lifetime (McClure 1989, 1995). Although natural mortality in HWA populations is commonly between 30 to 60 percent (McClure 1989, 1996), the reproduction potential of this insect remains high. This natural mortality is generally attributed to two likely causes: 1) an extended period of cold temperatures that coincides with a susceptible period of development for the adelgid, and/or 2) a sufficient loss in the nutritional quality and quantity of the food source, which is associated with the decline in health and vigor of the host tree (McClure 1996, Onken et al. 1999). Adelgid feeding can kill a mature tree in about 5 to 7 years (McClure et al. 2001). This tiny insect (~ 1 mm) feeds on all life stages of hemlock, from seedling to mature, old growth tree. Dispersal and movement of HWA is associated with wind, birds, deer, and other forest dwelling mammals. Humans also move the adelgid during logging and recreational activities (McClure 1995). Natural enemies capable of maintaining low-level HWA populations are nonexistent in eastern North America (Van Driesche et al. 1996, Wallace and Hain 1998).

HWA was first reported in the Western U.S. in the 1920s (Annand 1924, McClure 2001). HWA populations on western tree species, including western hemlock (*Tsuga heterophylla*) and mountain hemlock (*T. mertensiana*), appear to be innocuous; these tree species are believed to be resistant because little damage has been reported (McClure 2001). Unfortunately, both tree species are of limited value for hybridization and planting due to their poor adaptation to the east coast environment (Bentz et al. 2002). In the East, HWA was first reported in the 1950s near Richmond, Virginia. It was considered to be more of an urban landscape pest and was controlled using a variety of insecticides applied with ground spraying equipment. Observations of the adelgid were periodically reported in several Mid-Atlantic States in the 1960s and 1970s but it was not until the 1980s that HWA populations began to surge and spread northward to New England at an alarming rate. By the late 1980s to early 1990s, infestations of HWA were reported to be causing extensive hemlock decline and tree mortality in hemlock forests throughout the East (McClure 2001).

OBJECTIVES

The objectives of this biological evaluation are to: 1) assess current hemlock woolly adelgid population densities within hemlock stands at the Bird Run Campground (BRC), and 2) develop treatment alternatives and recommendations to reduce and/or control the hemlock woolly adelgid.

[2] The hemlock woolly adelgid also has a winged form that is produced by the overwintering generation. This form must complete part of its life cycle on spruce. The apparent lack of a suitable spruce host for this form in eastern North America results in a substantial loss of adelgids each year (McClure 1992b).

METHODS

The guidelines used to evaluate current population density and impacts include: 1) stand condition, 2) visual estimates of stand-level adelgid densities, 3) visual estimates of individual tree adelgid densities, and 4) visual estimates of tree condition. A 100 percent inventory of all hemlock trees (> 6" dbh) within the campground was used to provide the required information.

RESULTS

The survey area is represented in Figure 1. Hemlock woolly adelgid was found throughout the BRC. Infestation ranged from none to heavy (Appendix A) within the surveyed area (Table 1). Current HWA populations are high enough to cause reduced growth and future mortality of infested trees.

Figure 1. *Hemlock woolly adelgid survey area within the Bird Run Campground, Monongahela National Forest.*

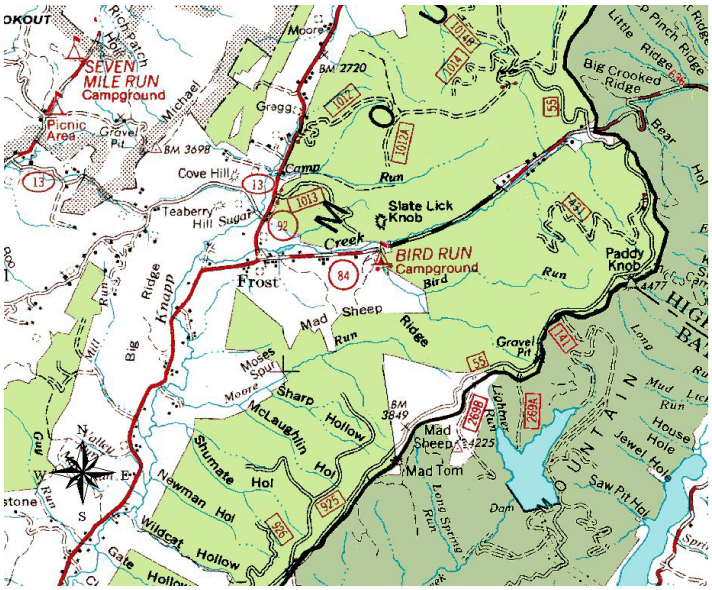

Table 1. *Hemlock woolly adelgid survey results for the Bird Run Campground, Monongahela National Forest, December 11, 2003.*

Number of Trees	DBH Size Range (inches)	HWA Infestation level
6	10-18	Heavy
21	6-23	Moderate
76	6-23	Light
9	6-15	None
1	.	Unknown

HEMLOCK MANAGEMENT ALTERNATIVES

Four management options have been evaluated for the hemlock trees at the Bird Run Campground. The intervention options were evaluated based upon the following objectives: 1) protecting hemlock timber and resource values and 2) reducing hemlock woolly adelgid populations in infested areas. Each option is discussed below.

Alternative 1: No Action

This alternative is considered the environmental baseline (the no action alternative). As a result, HWA populations would be allowed to increase and decrease naturally, without intervention. Because HWA has a high reproductive capacity and has demonstrated the ability to rapidly spread in recent years, it is expected that HWA populations will continue to increase throughout the Bird Run Campground and accelerate their spread to currently non-infested trees and stands within this area. Population densities will likely fluctuate periodically depending on the severity of winters, but rebound following such events, and consequently, impacts to hemlock resources throughout the campground will likely increase as more hemlocks succumb to this insect.

Alternative 2: Release *Pseudoscymnus tsugae* beetles (Recommended Action)

This alternative involves the release of laboratory reared *Pseudoscymnus tsugae* in hemlock woolly adelgid-infested hemlock trees for the purpose of accelerating the establishment of this predator beetle. The proposed releases would be conducted sometime in April 2004 and consist of the release of 5,000 *P. tsugae* beetles. Twenty-five HWA-infested trees will be selected at each site and approximately 200 beetles will be released per tree. Monitoring and evaluation efforts will continue for 3 years after release for the purpose of documenting the establishment and dispersal of the beetle and evaluating its effectiveness in reducing HWA population densities and protecting hemlock health on a stand-level basis. The New Jersey Department of Agriculture and Eco-Scientific Solutions (Scranton, PA) are currently rearing *P. tsugae* for this purpose. USDA Forest Service Forest Health Protection (FHP) entomologists will be providing a work plan with protocols to be followed for the 3-year project. USDA Forest Service FHP personnel will be responsible for conducting the releases, monitoring beetle dispersal and changes in HWA population densities, conducting tree health assessments, and reporting their results. Additional releases of *P. tsugae* beetles within this site are possible in the future based on beetle availability and monitoring results.

Pseudoscymnus tsugae is a tiny (~ 2 mm) coccinellid (ladybird) beetle native to Japan (Sasaji and McClure 1997) that was imported into Connecticut in 1994 (McClure and Cheah 1998), screened in quarantine, and evaluated to determine its suitability as a biocontrol agent for HWA in this country (Evans 2000). The life cycle of *P. tsugae* consists of the egg, four larval instars, the pupa, and the adult. Two overlapping generations per year are produced, and these coincide well with the two HWA generations. Adult and larval beetles feed on all life stages of the HWA (Hennessey and

McClure 1995). Host suitability tests (tests that determine whether an agent can complete development and reproduce), choice feeding tests, and host acceptance tests (tests that determine whether an agent will feed or reproduce on a host) indicate that *P. tsugae* will feed on and develop on other adelgid species (McClure and Cheah 1998) along with feeding on the woolly alder aphid (*Prociphilus tesselatus*) (Butin et al. 2002). Extensive laboratory and field tests in Connecticut have demonstrated that *P. tsugae* is an excellent natural enemy of HWA (Cheah 1998). In 1995, the USDA Animal and Plant Health Inspection Service (APHIS) issued Permit Number 950678 to the Connecticut Agricultural Experiment Station to release *P. tsugae* in Connecticut (Evans 2000). Since 1995, nearly 650,000 *P. tsugae* have been released in 11 Eastern States (McClure and Cheah 2002), including the Fanny Bennett Tract hemlock stand on the Monongahela National Forest in 2002.

This alternative would move forward with the release of *Pseudoscymnus* as a control for hemlock woolly adelgid. The goals and objectives of this study are listed below.

Project Objectives:

1. To introduce and establish *P. tsugae* in currently HWA infested hemlock stands.
2. To evaluate the impact *P. tsugae* has on HWA populations and to protect tree health at the stand level.

Long-term Goal:

To introduce and establish *P. tsugae* throughout the range of HWA, enhance the natural control of HWA in forest ecosystems, and reduce HWA impact on hemlock stands.

Alternative 3. Systemic Insecticides (Recommended Action)

This alternative involves the use of trunk-injected systemic insecticides for the purpose of reducing hemlock woolly adelgid populations on moderately to highly infested trees. The proposed treatment would be conducted in the fall of 2004 and consists of trunk injections of imidacloprid. Monitoring and evaluation efforts will continue for 3 years after treatment for the purpose of documenting the effectiveness of treatment in reducing HWA population densities and protecting hemlock health on an individual tree basis. USDA Forest Service Forest Health Protection entomologists will be providing a work plan with protocols to be followed for the 3-year project. Additional treatments within this site are possible in the future based on monitoring results.

Several types of systemic insecticides can be injected (e.g., imidacloprid, bidrin, or Metasystox-R®) or implanted (e.g., acephate) into hemlock trees, and another (Merit®) can be applied as a soil drench or injected into the soil around hemlock trees. These insecticides are absorbed and transported by the vascular system of the tree to feeding adelgids and will effectively suppress HWA populations (McClure 1992a, Steward and

Horner 1994, Evans 2000, Doccola et al. 2003, Webb et al. 2003). Unfortunately, many of these products are labeled for use on landscape ornamentals and interior plantscapes and not for forest settings. Because soil injection can cause leaching of the insecticide into the soil profile and ground water (McAvoy et al. 2002), this method of application was considered and dismissed. Of the trunk-injection systemic insecticides available, only imidacloprid marketed under the trade names Pointer®, Imi-jet®, or Imicide® is currently labeled for tree injection for the control of adelgids.

Imidacloprid

Imidacloprid is a relatively new insecticide in the family of chemicals called neonicotinoids (Felsot 2001) in the chloronicotinyl subgroup (USDA Animal and Plant Health Inspection Service 2002). It has a mode of action similar to that of the botanical product nicotine, functioning as a fast-acting insect neurotoxicant (Schroeder and Flattum 1984) that binds to the nicotinergic receptor sites in the postsynaptic membrane of the insect nerve (USDA Animal and Plant Health Inspection Service 2002), mimicking the action of acetylcholine, and thereby heightening, then blocking, the firing of the postsynaptic receptors with increasing doses (Schroeder and Flattum 1984, Felsot 2001). Because imidacloprid is slowly degraded in the insect, it causes substantial disorder within the nervous system, leading in most cases to death (Mullins 1993, Smith and Krischik 1999).

Imidacloprid is considered to have low to moderate mammalian toxicity[3] (Mullins 1993). Chronic (repeated dose) toxicity studies have demonstrated that imidacloprid is not carcinogenic and is not mutagenic and demonstrates no primary reproductive toxicity (Mullins 1993). In studies of metabolic fate in rats, imidacloprid was rapidly absorbed and eliminated in the excreta (90 percent of the dose within 24 hours) with little bioaccumulation (0.5 percent of the dose after 48 hours) and no biologically significant differences occurring between sexes, dose level, and route of administration (USDA Animal and Plant Health Inspection Service 2002). Imidacloprid is an insecticide exhibiting both systemic and contact activity. The spectrum of activity primarily includes sucking insects (aphids, whiteflies, leaf and plant hoppers, thrips, plant bugs, and scales), many Coleopteran species, and selected species of Diptera and Lepidoptera. Activity has also been demonstrated for ants (Hymenoptera); termites (Isoptera); and cockroaches, grasshoppers, and crickets (Orthoptera). No activity has been demonstrated against nematodes or spider mites (Mullins 1993). In spider mites, imidacloprid has been demonstrated to cause an egg-laying enhancement (James and Price 2002). Since spider mites can be a problem in hemlock, any imidacloprid-treated tree should be carefully monitored for increases in mite populations.

[3] Largely because it does not bind nerve receptors in mammals sufficiently to trigger nervous activity (Felsot 2001). The selective toxicity of imidacloprid is perhaps best illustrated by its use in flea treatments approved for cats and dogs. Advantage® is applied directly to the animal's skin; this preparation carries very little, if any, risk to the animal or to the people, including children, who may handle the animal (USDA Animal and Plant Health Inspection Service 2002).

Little is known of the biotransformation and bioactivity of the metabolites of imidacloprid in plants. What is known is that trunk injected imidacloprid generally requires a week or longer to provide adelgid control, with protection lasting for up to two years (Tater et al. 1998, Silcox 2002).

Alternative 4. Other Control Alternatives Considered, but Dismissed

4.1 Ground spraying with horticultural oils, insecticidal soaps and foliar insecticides

These methods of treatment can be effective in situations where there is access to the trees for ground spraying equipment, including pumping trucks with high-pressure hoses, and the entire crown of each tree can be saturated with the spray (Evans 2000). Although this type of access is available at the BRC, concerns for drift into Bird Run Creek caused this alternative to be dismissed.

4.2 Aerial spraying

Aerial spraying with horticultural oils or insecticidal soaps is not an effective treatment because it fails to provide the needed "saturation" coverage of each tree crown. Aerial spraying with more toxic insecticides (e.g. malathion or diazinon) would have very significant, unacceptable impacts on a wide range of non-target insects and other animals (Evans 2000). Therefore, this alternative was considered infeasible and was dismissed.

4.3 Pheromone traps, or other methods of disrupting reproduction

Because HWA reproduces asexually (Its populations are entirely parthenogenetic; females reproduce without males), it is not possible to disrupt reproduction through pheromone traps or other, similar methods (Evans 2000). Therefore, this alternative was considered infeasible and was dismissed.

RECOMMENDATIONS

It is recommended that the MNF decide in favor of Alternatives 2 and 3 (release and establishment of *P. tsugae;* trunk injections of the systemic insecticide imidacloprid) in the Bird Run Campground. Host acceptance tests and choice tests have demonstrated that *P. tsugae* will feed on non-target adelgid species and the possibility exists that these other adelgid and aphid species may be fed on. Imidacloprid is a systemic and contact insecticide exhibiting low to moderate mammalian toxicity, with primary activity on sucking insects. With each of these treatment options comes the potential for non-target effects; land managers must balance the risk of these effects with the potential benefits that come with the control of the HWA. Introduction of *P. tsugae* is expected to reduce the impact of HWA and may provide lasting and effective control in a cost-efficient manner. Trunk injections of imidacloprid are expected to reduce HWA populations on moderate to heavily infested trees and provide one to two years of protection.

ADDITIONAL INFORMATION

Could *P. tsugae* impact other native predators or parasites that rely on HWA as a food source?

There are no known parasites of HWA in either this country or its country of origin. There are no other arthropod species listed as endangered or threatened at the Federal or State level that utilize HWA as a food source; hence, no such species will be affected by the release of *P. tsugae.*

Of the native or introduced beetles found in the natural hemlock habitat, none appear to be dependent on HWA and all have an alternate host preference. Beetle predators sometimes found associated with hemlock habitat include the twice stabbed lady beetle (*Chilochorus stigma*), which predates on hemlock scales; the Halloween beetle (*Harmonia axyridis*), which primarily feeds on aphids but will opportunistically feed on adelgid; *Scymnus suturalis,* a common predator of *Pineus* adelgids, that occasionally can be found feeding on HWA; and *Laricobius rubidus*, a derodontid beetle that feeds primarily on *Pineus strobi* on white pine but will also feed on HWA (Montgomery 1999). Brown lacewing, midge, and syrphid larvae have also been observed in association with HWA in Connecticut but in low numbers (Montgomery 1999); these larvae are sometimes associated with egg masses of the HWA at low densities but all are generalists and prey on mites, aphids, and other insect larvae (Cheah 1998). None of these predators, either individually or collectively, have a substantial impact on HWA populations (Montgomery and Lyons 1996).

Could *P. tsugae* become a nuisance to human habitations?

Behavioral studies indicate that *P. tsugae* does not aggregate in large numbers (McClure and Cheah 1998), as was the case with another non-indigenous lady beetle, *Harmonia axyridis that* was introduced into the U.S. for biological control of aphids. *P. tsugae* does not leave the forest during the winter, but remains in bark crevices or in the litter on the forest floor (McClure and Cheah 1998) during periods of extreme cold.

Could trunk injections of Imidacloprid impact other non-target organisms?

Yes. Imidacloprid is effective against a wide range of insect species. The following will be exposed to the effects of this insecticide: any sap- or foliage-feeding insect or its predators (including *P. tsugae*) or parasites, deer, and insectivorous and sap-feedings birds[4] that feed directly on the foliage, sap, or seeds of a treated hemlock tree.

[4] In studies with red- winged blackbirds and brown-headed cowbirds, it was observed that birds learned to avoid imidacloprid (at the projected recommend rate on the pesticide label) treated seeds after experiencing transitory gastrointestinal distress (retching) and ataxia (loss of coordination). It was concluded that the risk of dietary exposure to birds via treated seeds was minimal (Avery et al. 1993).

Could trunk injections of Imidacloprid contaminate ground water along Bird Run Creek?

By using trunk injection as our application method, we greatly reduce the potential for ground water contamination by creating a nearly closed treatment system. Imidacloprid taken up by the tree's transport system is expected to move upward and downward within the tree (Tattar and Tattar 1999) but remain sequestered in the tree's tissue and not be available on the surface of roots, wood, or leaves (USDA Animal and Plant Health Inspection Service 2002).

Could trunk injections of Imidacloprid impact or damage trees?

Yes. Trunk injections sever xylem cells, break the continuity of the water column at the area of injection, introduce air into cells, initiate a wound healing response in the tree, and can create a port of entry for decay and disease (Chaney 1986). Fortunately, hemlocks have no aggressive stem diseases and very few heart rots[5] (decay) that attack living trees. The fungi that do attack hemlock are considered weakly parthenogenic or nonparthenogenic (Hepting 1971).

[5] Heart rot is decomposition of the central stem wood of living trees. Heart rot or decay is caused by numerous species of fungi and is the most damaging of all tree diseases (Helms 1998).

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APPENDIX A

#	TAG_NUM	DBH	HWA_INFEST_LEVEL*		#	TAG_NUM	DBH	HWA_INFEST_LEVEL*
1	201	6.6	Light		42	241	9.4	Light
2	202	6.9	Light		43	242	10.2	Light
3	203	7.5	Light		44	243	7.6	Light
4	204	8.6	Light		45	244	6.3	Light
5	205	10.4	Light		46	245	7.3	Light
6	206	13.5	Light		47	246	8.3	Light
7	207	10.0	Heavy		48	247	7.6	Light
8	208	8.3	Light		49	248	7.4	Light
9	209	9.7	Moderate		50	249	9.0	Light
10	210	13.5	Light		51	250	6.7	Light
11	211	9.8	Light		52	251	7.5	Light
12	212	6.2	Light		53	252	6.7	Light
13	213	7.2	Light		54	253	6.9	Light
14	214	16.4	Light		55	254	8.1	None
15	215	7.0	Light		56	255	6.2	None
16	217	7.5	Light		57	256	7.4	Light
17	218	8.0	Light		58	257	14.7	None
18	219	12.5	Light		59	258	7.2	None
19	220	8.2	Light		60	259	6.3	Light
20	221	9.3	Light		61	260	6.9	Light
21	222	6.3	Light		62	261	6.3	None
22	223	7.1	Light		63	262	11.4	Light
23	224	8.5	Light		64	263	6.9	Light
24	225	11.7	Heavy		65	264	12.5	Moderate
25	226	15.7	Light		66	265	6.3	Light
26	227	9.5	Light		67	266	7.7	Light
27	228	8.0	Light		68	267	.	Unknown
28	229	8.4	Light		69	268	17.8	Moderate
29	230	8.6	Moderate		70	269	9.8	Light
30	231	7.2	Light		71	270	8.8	Light
31	232	8.5	Moderate		72	271	7.4	Light
32	233	7.3	Light		73	272	22.6	Light
33	234	7.4	Light		74	273	8.5	Light
34	233	7.4	Light		75	274	13.5	None
35	234	9.4	Light		76	275	13.8	None
36	235	15.3	Light		77	276	7.4	None
37	236	12.6	Moderate		78	277	18.4	Moderate
38	237	7.3	Moderate		79	278	6.2	Moderate
39	238	7.0	Light		80	279	17.9	Heavy
40	239	7.3	Moderate		81	280	10.8	Moderate
41	240	9.4	Light		82	281	8.8	Moderate

*Based on visual estimates from 3-5 hemlock branches: Heavy = (>50% of new growth [NG] infested), Moderate = (50% to 25% of NG infested), Light = (<25% of NG infested), None = (0% infested)

APPENDIX A (continued)

#	TAG_NUM	DBH	HWA_INFEST_LEVEL*		#	TAG_NUM	DBH	HWA_INFEST_LEVEL*
83	282	17.9	Heavy					
84	283	18.0	Light					
85	284	11.5	Moderate					
86	285	12.2	Moderate					
87	286	15.6	Light					
88	287	12.2	Light					
89	288	7.3	Moderate					
90	289	8.6	Moderate					
91	290	6.7	Moderate					
92	291	11.0	Moderate					
93	292	14.0	Heavy					
94	295	23.1	Moderate					
95	296	20.2	Moderate					
96	872	6.7	Light					
97	873	7.5	Light					
98	874	14.3	Light					
99	875	7.3	Light					
100	876	7.0	Light					
101	877	6.2	Light					
102	878	11.8	Light					
103	879	7.8	Light					
104	880	8.4	Light					
105	881	7.2	Light					
106	882	11.0	Light					
107	883	8.3	None					
108	884	6.5	Light					
109	885	8.3	Light					
110	886	6.4	Light					
111	888	7.7	Light					
112	889	19.9	Moderate					
113	890	17	Heavy					

*Based on visual estimates from 3-5 hemlock branches: Heavy = (>50% of new growth [NG] infested), Moderate = (50% to 25% of NG infested), Light = (<25% of NG infested), None = (0% infested)